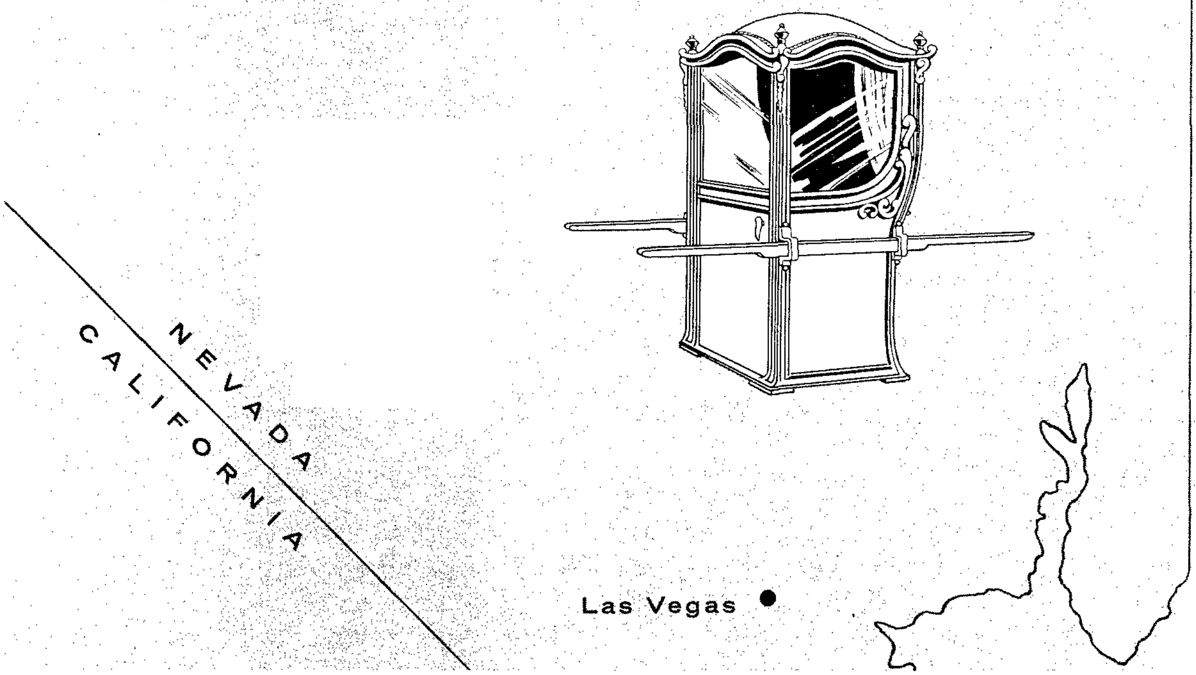
PNE-202F
FINAL REPORT

Plowshare / peaceful uses for nuclear explosives

UNITED STATES ATOMIC ENERGY COMMISSION / PLOWSHARE PROGRAM

project SEDAN

NEVADA TEST SITE / JULY 6, 1962



Sedan Long Range Blast Propagation

Jack W. Reed / Hugh W. Church

SANDIA CORPORATION

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Project Plowshare

SEDAN LONG RANGE BLAST PROPAGATION

Final Report

Jack W. Reed

Hugh W. Church

Sandia Corporation, Albuquerque, New Mexico

June 1963

ABSTRACT

Microbarograph records of air-blast waves from the Sedan shot were made at eight stations in California and Nevada at ranges from 100 to 230 miles. A 1.2-ton high-explosive calibration shot was fired at Sedan minus 2 minutes to establish propagation conditions for bursts in air. Comparison of recorded signals indicated that Sedan blast-wave amplitudes averaged 20 percent of amplitudes which would have been transmitted had the Sedan yield been free-air burst. Individual transmissivity values ranged from 5 to 35 percent. Variations around the average are probably caused by atmospheric turbulence.

Sedan blast waves were ducted toward the west by atmospheric refraction in the ozonosphere where strong summer easterlies were blowing at 100,000- to 200,000-foot altitudes. Rocket wind measurements were made at Tonopah Test Range. Rocket and rawinsonde data were used to calculate atmospheric blast propagations which are in fair agreement with microbarograph measurements.

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SEDAN LONG-RANGE BLAST PROPAGATION

INTRODUCTION

The Sedan shot was a 100-kiloton nuclear device burst 635 feet below the surface in Yucca Flat, Area 10, of the Nevada Test Site (NTS). Shot time was 1000 PDT, July 6, 1962. The test was conducted to give cratering effects data on nuclear excavation in desert alluvium. Results are to be applied to the design and safety evaluation of future Plowshare nuclear excavations.

Microbarograph measurements were made at ranges to 230 miles to provide data for scaling and the assurance of off-site safety of future larger cratering experiments. Similar measurements on Plowshare high-explosive (HE) tests[1,2,3] have shown approximately how air-blast transmissions were decreased with increased scaled depth of burst. This transmissivity appeared to be larger for shots in basalt (Buckboard)[2] than for shots in alluvium (Stagecoach).[1] Transmissivity appear to increase with increased yield in Stagecoach-versus-Scooter[3] comparisons. It was believed that there would also be a difference between nuclear and high-explosive transmissivities, but comparison between Teapot ESS[4] and the Stagecoach shallow shot did not show any clear difference. There were no other nuclear tests at depths near the optimum for cratering in similar environments.

During the 1958-61 test moratorium, rocket upper wind measurements were made operationally feasible so that ozonosphere weather conditions could be observed. These observations could be used to calculate ozonosphere sould refraction and blast ducting as was done in previous years for tropospheric ducting for the purpose of making predictions for off-site safety. Sedan, Dannyboy,[5] and Smallboy shots provided the only opportunities thus far encountered at NTS to test these high-altitude blast pattern calculations.

EXPERIMENT PLAN

In summer, ozonosphere winds at 100,000- to 200,000-foot altitudes blow from east to west and, from Nevada, refract blast waves into California, with

a caustic ring of relatively strong waves landing at between 100 and 150 miles from surface zero. Waves in this ring reflect from ground, repeat the high atmosphere path, and land again at 200 to 300 miles, etc. To study this pattern, microbarograph stations were operated at eight sites in the southwest-northwest quadrant from NTS as shown in Fig. 1. Shot and microbarograph location coordinates and connecting bearings and ranges are listed in Table 1.

It was planned to fire 1.2-ton high-explosive calibration shots at H minus 2 minutes and H plus 3 minutes to record the general propagation of known-yield air blasts. Comparison of signals from these shots with the intervening Sedan signal would allow calculation of the air-blast attenuation factor or its inverse, the transmissivity, from the buried nuclear device.

Near shot time, a rocket wind measurement of ozonosphere winds and a balloon-borne rawinsonde measurement of troposphere winds and temperatures were to be made. Weather data from these soundings were to be used to compute directed sound velocities at various altitudes. From the sound velocity structure a computation of refracted sound-ray paths could be made on the Raypac computer at the NTS control point (CP-1). This analogue sound-ray computer is shown in Fig. 2. Sound-ray paths indicate where a blast wave would return to ground, and the ray spacing, when combined with blast yield, allows a calculated pressure-amplitude prediction. Calculated predictions were to be compared with signals from both the HE calibration shots and the Sedan signal to give statistical information on prediction errors. Also, the three event records (two HE and one nuclear) of the blast signals at each station could be compared to show short-term variability of atmospheric propagations caused by turbulence.

Finally, results were to be scaled up to larger yields to demonstrate the magnitude and relative importance of blast safety predictions.

INSTRUMENTATION

Microbarographs used for this project were similar to those used for years in recording nuclear tests. Differential pressure-wave sensors were twisted Bourdon tubes which turned an armature with respect to an E-core. Varying reluctance in the E-core is used to modulate a carrier wave transmitted by

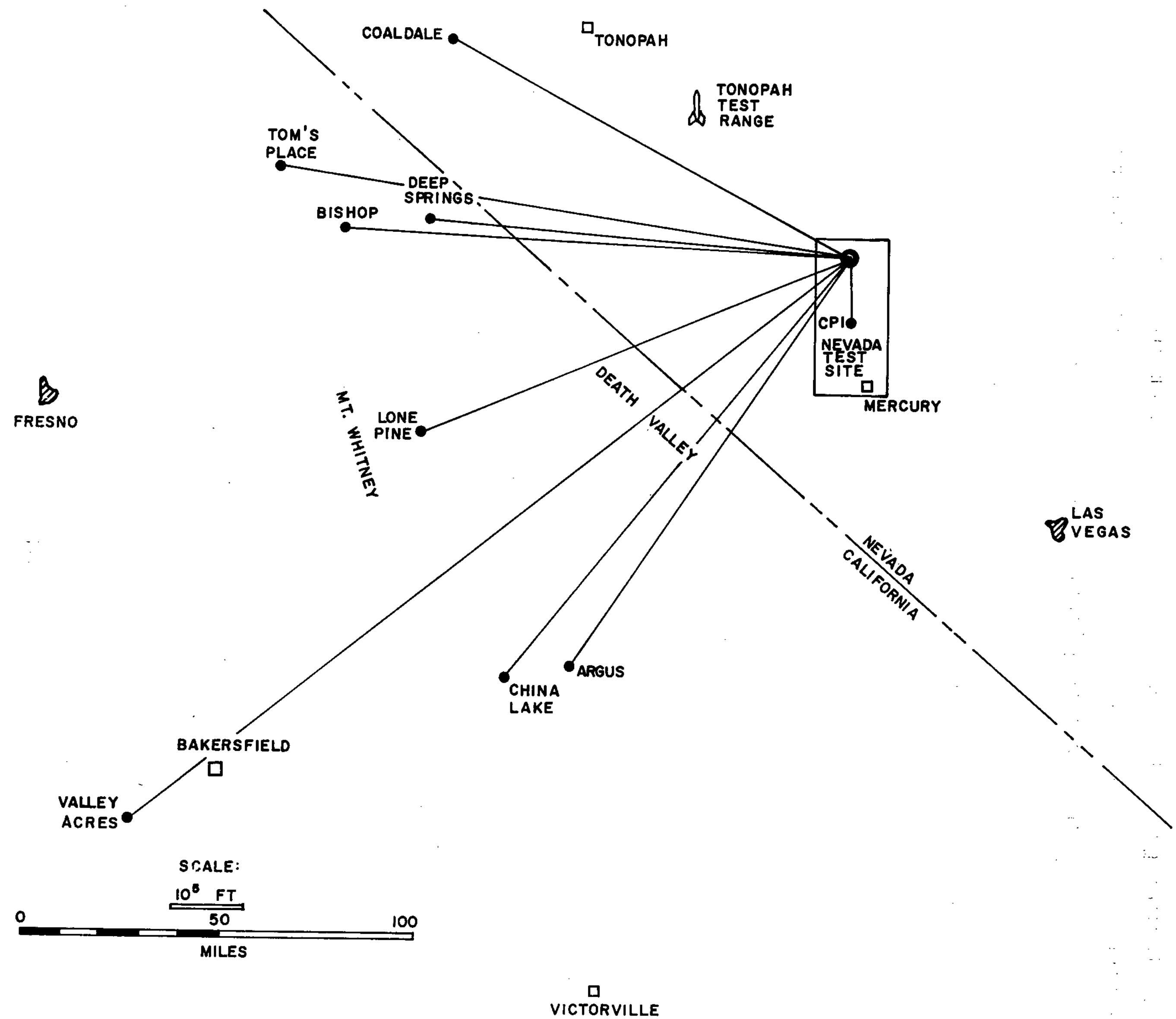

Fig. 1 Sedan microbarograph stations.

Table 1. Bearings and Ranges from Shot Points to Microbarograph Stations

Station	Sedan	HE calibration
	37° 10' 37.225" North 116° 02' 43.359" West Elevation 4323 ft MSL	37° 10' 43.668" North 116° 01' 13.791" West Elevation 4423 ft MSL
CP-1 36° 56' 04.896" N El. 4120' 116° 03' 12.800" W	181.55° 88,440'	186.18° 89,580'
Argus 35° 42' 55.417" N El. 1750' 117° 24' 07.303" W	217.15° 665,473'	217.63° 670,383'
China Lake 35° 41' 34.363" N El. 2200' 117° 40' 51.998" W	222.05° 723,652'	222.45° 728,999'
Valley Acres 35° 12' 19.185" N El. 600' 119° 24' 10.327" W	234.96° 1,222,440'	235.14° 1,228,740'
Lone Pine 36° 35' 24.023" N El. 3700' 118° 03' 17.139" W	250.54° 624,248'	250.72° 631,288'
Deep Springs 37° 22' 21.535" N El. 5300' 117° 59' 52.753" W	277.77° 571,360'	277.62° 578,440'
Bishop 37° 21' 26.221" N El. 4190' 118° 23' 47.147" W	276.21° 685,778'	276.11° 692,899'
Tom's Place 37° 33' 38.438" N El. 7050' 118° 40' 43.713" W	281.19° 776.331'	281.05° 783,303'
Coaldale 38° 01' 35.940" N El. 4630' 117° 52' 54.087" W	300.84° 614,679'	300.46° 620,568'

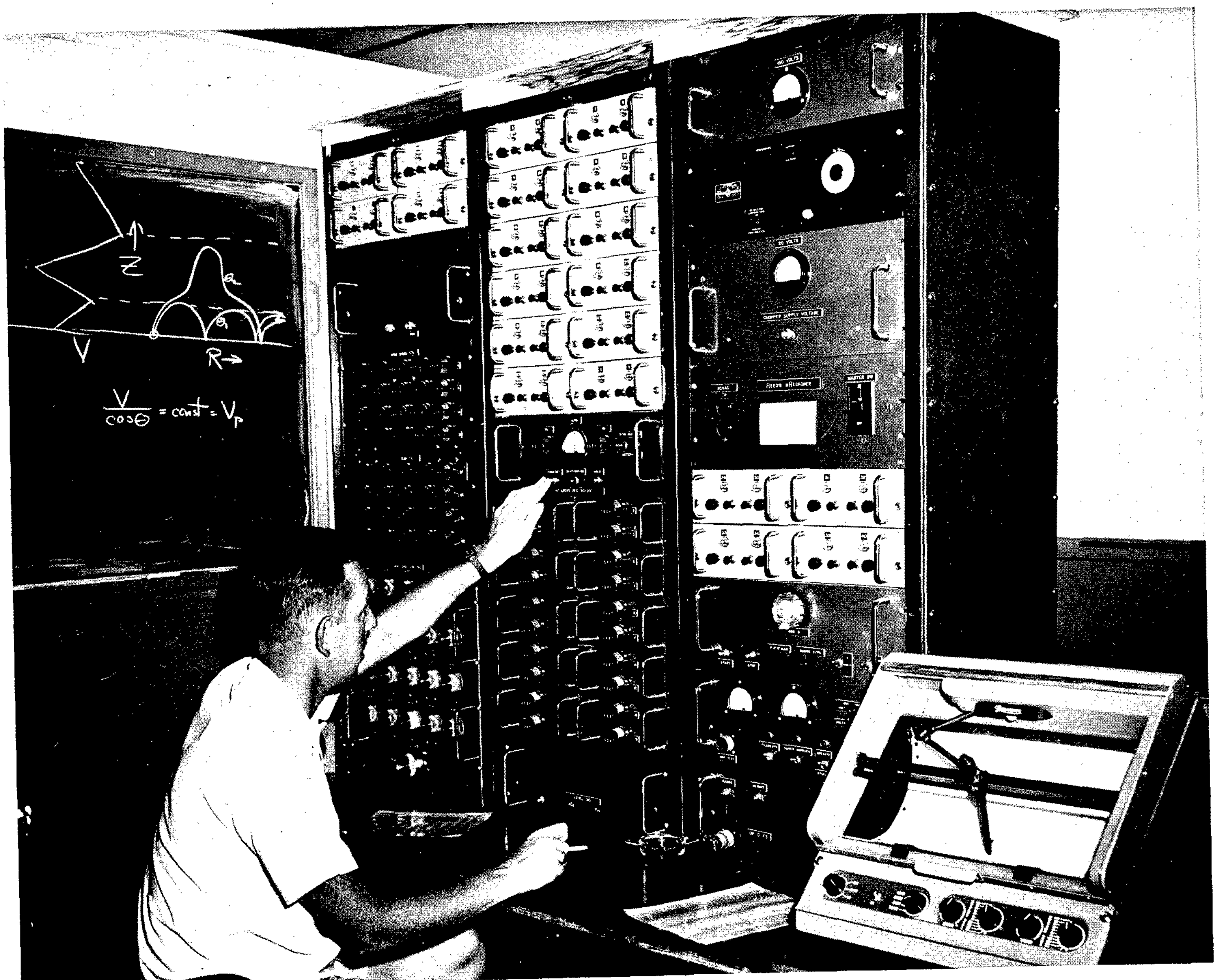

Fig. 2 Raypac (Atmospheric Sound Ray Computer) and plotter at CP-1, NTS.

coaxial line into appropriate signal amplifiers for recording. Sensor heads were manufactured by Wiancko Corporation, Pasadena, California, as specified and evaluated by Sandia Corporation.[6] Amplifier and timer systems in current use were designed at Sandia and built by the Electronic Engineering Company, Santa Ana, California. Brush Electronics Company pen-type recorders were used at a paper speed of 2.5 centimeters per second, with 1-second time marks by an event-marking pen. Zero-time signals for both calibration and Sedan shots were transmitted on NTS Net 12 radio and recorded on each pressure trace. Combined instrument and recorder response time for pressure signals was such that 95 percent of pen deflection from a square-wave pressure pulse would be recorded in about 15 milliseconds. Thus, there is very little amplitude damping for signals having frequencies lower than 10 cps.

Sandia microbarographs have seven set-range switch positions, which allow signal amplitudes from 1 microbar to 48 millibars* to be satisfactorily recorded, provided ambient wind noise at low signal levels and blast damage at high pressure levels are not excessive. Recent calibration tests have disclosed that nearly 85 percent of all recordings were accurate to ±20 percent.

Wind rockets were launched from Tonopah Test Range (see Fig. 1) after the Sedan shot was fired. A Judi rocket motor, manufactured by Rocket Power, Inc., Phoenix, Arizona, carried a Dart payload nose to 255,000 feet msl. This 30-pound system carried a 1.5-pound payload of copper-wire chaff, each piece 5 cm long and 5×10^{-3} inch in diameter. Chaff of this size falls freely to about 200,000 feet where air density and drag become sufficient to carry it with the wind as it falls down to around 50,000 feet. Timed chaff-cloud tracks reported by a modified MPS-25 radar furnished wind observations through height layers. Sandia rocket wind measurements have been analyzed and reported by Smith.[7] These winds were used with sound speeds derived from ARDC 1962 Standard Atmosphere temperature data[8] from 90,000 feet to approximately 188,000 feet, as shown in Table 2. Rawinsonde balloon observations of the troposphere and low stratosphere were made by the U.S. Weather Bureau in Yucca Flat from ground level to 86,000 feet msl.

*1 millibar = 10^3 dynes/cm^2 = 0.0145 psi ≈ 10^{-3} atmospheres (STP).

Table 2. Upper Air Observations used for Sound Ray Calculations

Height (kilofeet, msl)	Temperature (^{o}C)	Wind direction (degrees)	Speed (knots)
4	+31.0	180	10
5	+26.5	150	13
6	+23.5	155	12
7	+20.5	177	10
9	+14.6	230	14
11	+8.8	197	28
14	+3.5	180	21
17	-0.6	188	6
23	-15.0	250	1
28	-25.7	296	6
33	-37.6	237	22
42	-54.5	250	35
50	-65.2	225	25
54	-67.8	229	12
60	-62.5	180	16
65	-56.0	115	14
80	-49.8	100	28
86	-45.3	070	18
105	-44.8	090	32
120	-32.5	095	45
140	-16.0	093	60
155	-2.5	100	102
170	-2.5	102	84
180	-7.0	110	80
188	-12.0	095	127

RESULTS

Sedan was fired, as previously mentioned, at 1000 PDT, July 6, 1962. One HE calibration shot was fired at 0958 PDT on schedule. The Sedan shot, however, severed the firing cables to the site for a later scheduled HE firing, and the latter calibration shot could not be detonated. Rocket wind measurements were made at Tonopah Test Range at 1005 PDT and at 1630 PDT. Most microbarographs appeared to have operated satisfactorily, and recordings were made of both shots. Postshot calibrations from the Bishop station, however, showed that instrument response was nonlinear and probably incorrect at low pressure amplitudes. Data from this station are therefore suspect, particularly the HE signal pressure, although the Sedan recording seems to be in line with surrounding data points. In addition, at the Coaldale station there was considerable electrical noise (6 cps) on the recording which undoubtedly produced HE pressure signal deflections greater than were anticipated. This did not adversely affect the lower frequency, higher amplitude Sedan recording.

Sedan pressure amplitudes were somewhat larger than expected and caused a slightly off-scale recording at China Lake. The Lone Pine operator erroneously used too sensitive a set range, and the recording was likewise driven off-scale by the Sedan wave. The Tom's Place recording shows a long, flat pressure maximum which may well have been the set-range limit.

A summary of major significant signal data is shown in Table 3, and the most interesting portions of the various recordings are shown in Figs. 3 and 4. Maximum amplitudes are shown on a pressure-distance plot in Fig. 5 for comparison with standard curve values. Observed pressures have been scaled to near sea level values at 1000 millibars ambient pressure for comparison with standard values. Ambient pressure at each station was taken from U.S. standard pressure altitude tables[8] for the surveyed station elevation. Actual barometric pressure values would provide only sight correction beyond this adjustment.

The standard reference curves were derived from the IBM Problem M calculation[9] for a 1-kiloton free-air-burst nuclear device at sea level (1000 mb). This calculation was carried only to 9000 feet range, 0.37 psi (25.5 mb) overpressure. At longer range, R, overpressure, Δp, follows $\Delta p \sim R^{-1.2}$ in a homogeneous, nonrefracting atmosphere. In the IBM Problem M, negative-phase pressures approach

Table 3. Sedan Microbarograph Data Summary

Station	Calibration shot			Sedan			
	t_a	p_k	V	t_a	p_k	V	Remarks
CP-1	81.4	41.0	1100	80.7	1394	1095	HE deflection very small.
Argus	~ 673	46.8	~ 997	~ 664	376	~ 1001	Timer troubles, t, V inaccurate.
China Lake	753	51.0	969	748	>828	967	Slightly off-scale.
Valley Acres	1177	6.2	1043	1172	106	1043	
Lone Pine	671	41.0	942	656	>328	951	Possibly factor of 2 off-scale on Sedan.
Deep Springs	615	107	940	605	555	945	
Bishop	714	13.8	970	708	685	969	Doubtful amplitudes.
Tom's Place	791	67.0	990	785	>750	990	Sedan signal may have limited.
Coaldale	654	130	951	645	320	954	Max. HE value may be electric interference.

NOTE: t_a is arrival time in seconds;
p_k is peak-to-peak pressure amplitude in microbars;
V is average propagation speed in ft/sec.

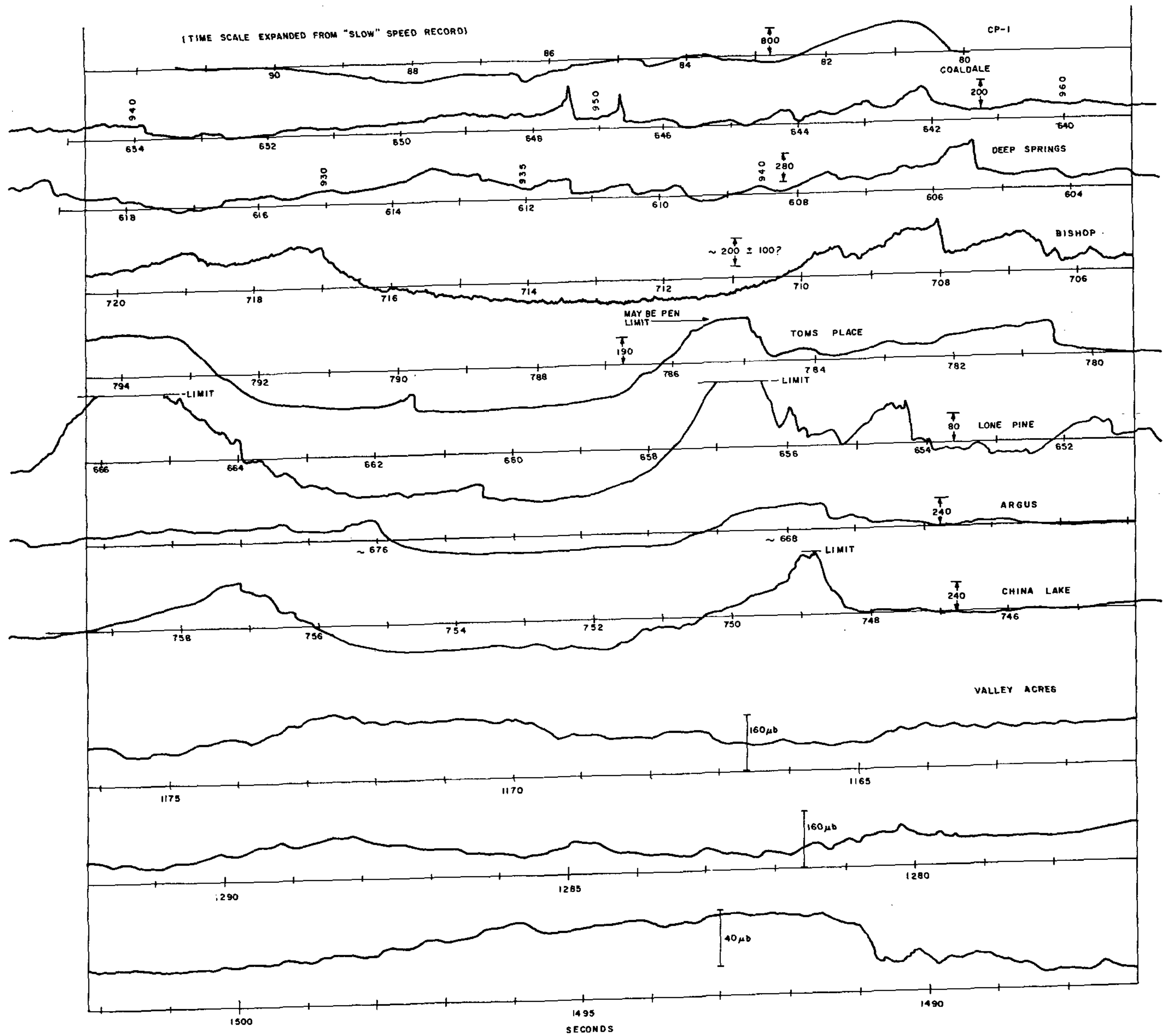

Fig. 3 Sedan microbarograph recordings.

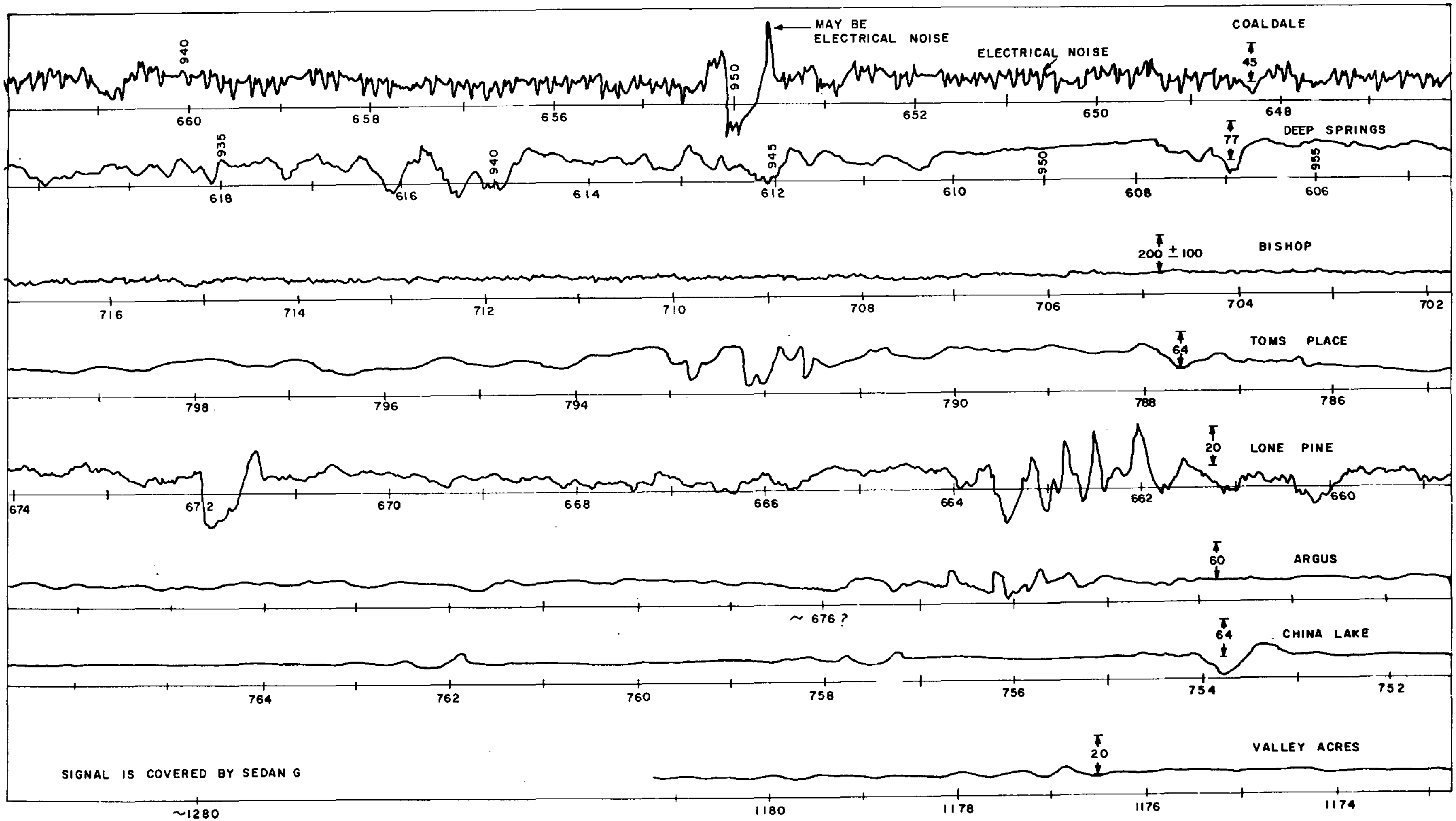

Fig. 4 Microbarograph recordings of HE calibration shot fired at Sedan minus 2 minutes.

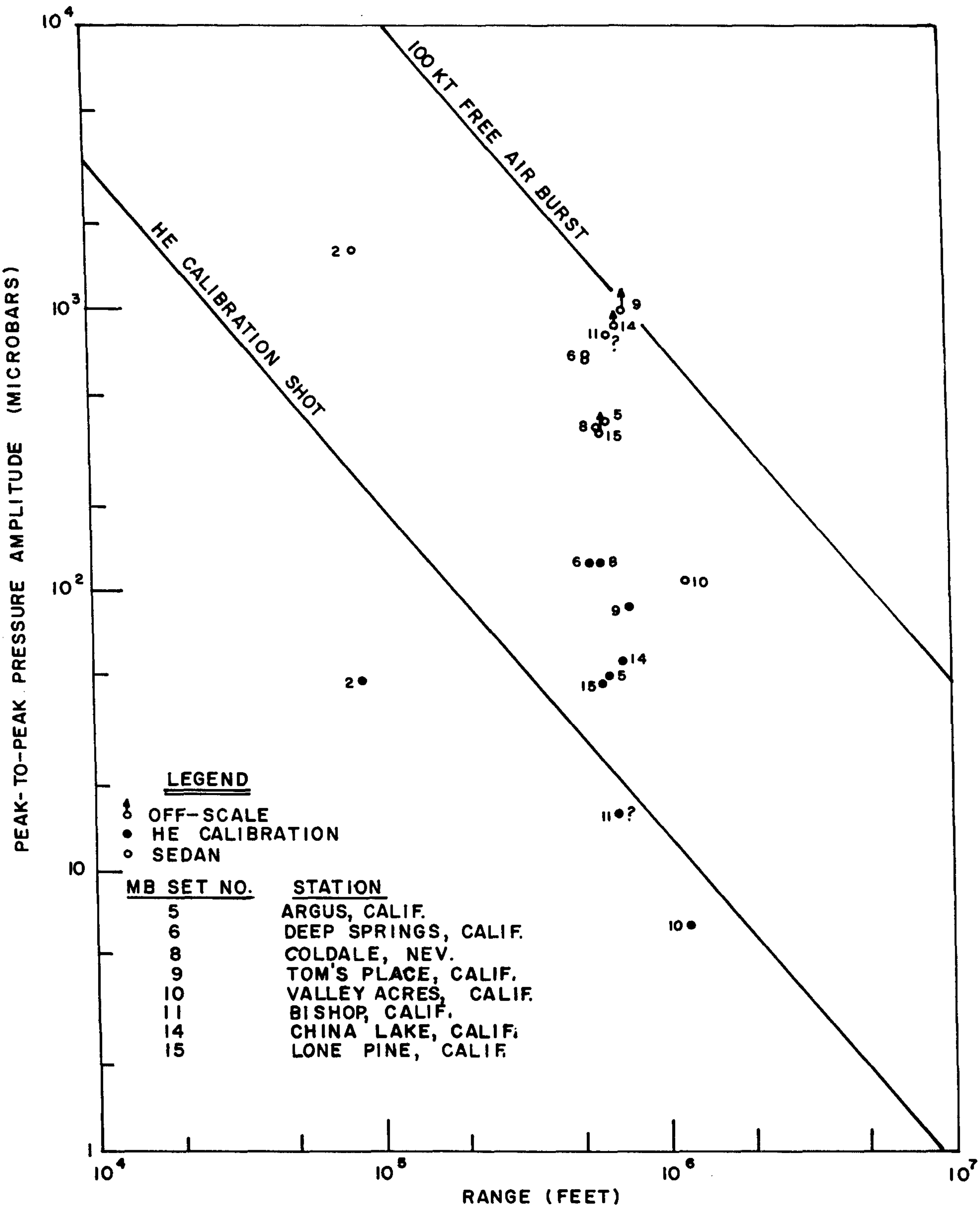

Fig. 5 Maximum pressure-wave amplitudes.

0.34 times the overpressure; from this, peak-to-peak pressure amplitude, p_k, at large distance is assumed to conserve this relation so that $p_k = 1.34\ \Delta p$.

The calibration shot was 1.2-ton uncased high-explosive (TNT) placed on a wooden platform 15 feet above ground, similar to the one shown in Fig. 6. At this height of burst, the blast wave was equivalent to a wave from 2.1 tons HE, free-air burst. The end point of IBM Problem M, 25.5 mb at 9000 feet range, was scaled to give $p_k = 1.34 \times 25.5 = 34.2$ mb at $R = 9000\ (4.2\ \text{t}/1\ \text{kt})^{1/3} = 1452$ feet. Beyond this range, $p_k = 53.5\ (R\ \text{kft})^{-1.2}$ mb.

The apparent HE blast-yield enhancement caused by height-of-burst effects was derived from data published by Vortman and Shreve.[10] Effects of height of burst on blast pressures propagated to long range are according to Church.[11] Calibration HE shots were first fired on towers during the Buckboard project. On Stagecoach they were fired at ground level. There remains some doubt that the surface burst apparent yield value, 0.6W, used in Stagecoach, is correct. If a larger value, i.e., 1.6W, as is generally used for nuclear surface bursts, is more appropriate, Stagecoach transmission factors should be increased by $(1.6/0.6)^{0.4} = 1.48$. This would result in negating previous conclusions that (1) transmissivity from shots in basalt is larger than from shots in alluvium, and (2) transmissivity increases with increased yield. Church's experiments with HE spheres half-buried for zero height of burst, in addition to two pressure-gage measurements at 300 feet from 1.2 tons of depth charges lying on the ground, are not sufficient to adequately ease these doubts. Other more direct tests, comparing 1.2-ton HE tower bursts with surface bursts, should be made.

Sedan, with a yield of 100 kilotons (nuclear), if free-air burst, would have given a standard pressure-distance curve beginning at $p_k = 34.2$ mb at $R = 9000\ (100\ \text{kt}/1\ \text{kt})^{1/3} = 41{,}800$ feet, and would have followed $p_k = 3010\ (R\ \text{kft})^{-1.2}$ to longer ranges. Figure 5 shows that some of the Sedan pressures (off-scale records) probably exceeded standard values for air bursts. Since the HE calibration records greatly exceeded the standard homogeneous atmosphere propagations, Sedan results are not surprising. Atmospheric ducting and focusing toward this downwind sector of observation stations on this particular day caused considerable enchancement of pressure amplitudes from both shots.

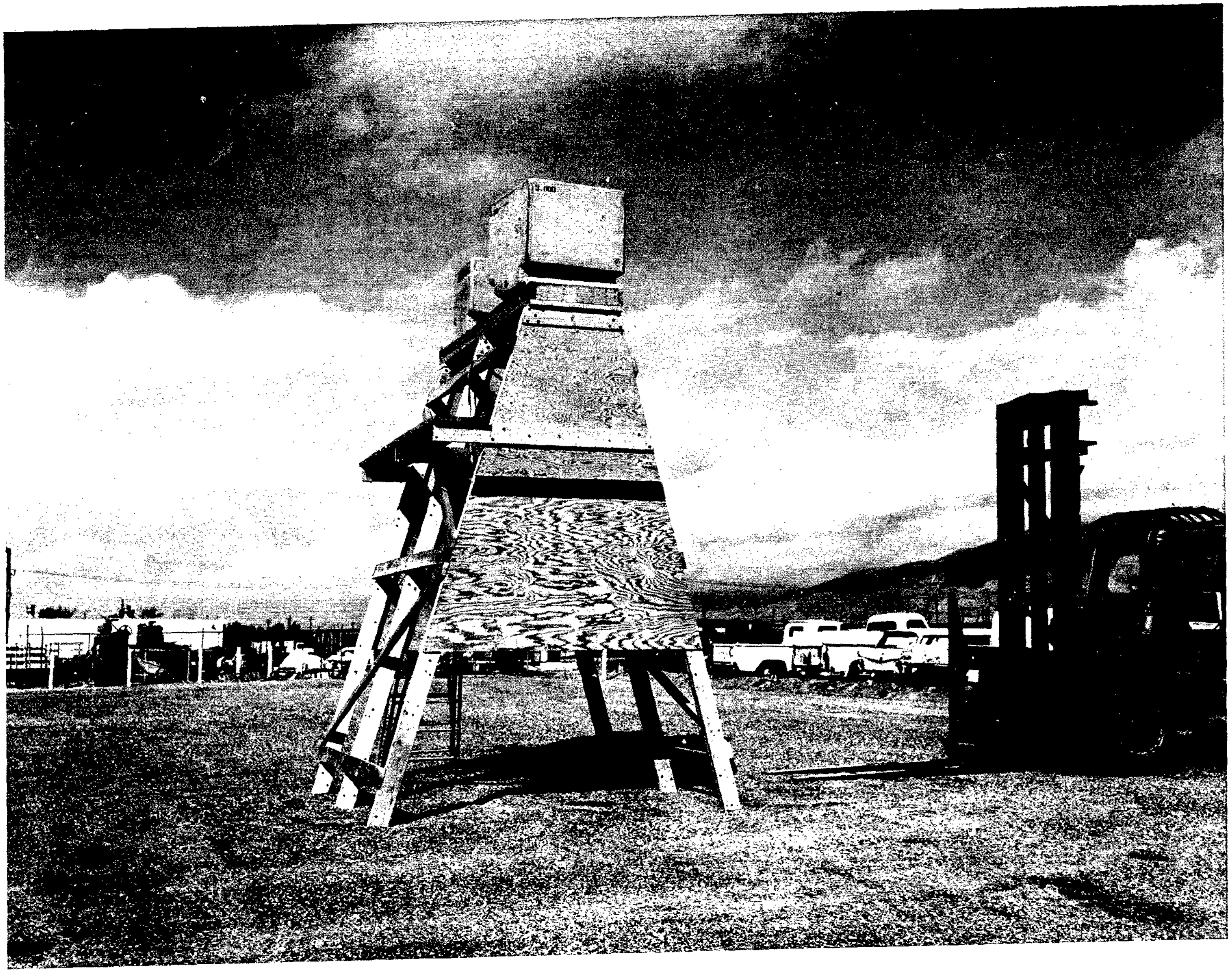

Fig. 6 Platform used in firing HE calibration shots; height, 15 feet.

Records from CP-1, at too short a range to receive ozonosphere propagations, show pressures much below standard characteristics of propagation upwind in an unstable atmosphere, where sound velocity decreases with altitude to refract blast waves away from ground level. Because of shot-point and azimuth-bearing differences from the two shots, HE propagation was more obscured from CP-1 than was propagation from Sedan, and in result was more reduced below the standard curve.

Transmission factors for the Sedan underground burst were calculated by extrapolation from HE calibration shot pressures to give predictions for a 100-kiloton free-air burst. In this extrapolation, HE amplitudes were multiplied by $(100\ kt/4.2\ t)^{0.4} = 56.1$, and the product was divided into observed Sedan pressure amplitudes to give the transmission factor. The 0.4 yield exponent follows directly from the scaled distance proportionality to the cube root of yield in a region where overpressure decays as $R^{-1.2}$. Each recorded Sedan wave, which clearly followed the same path (same mean travel velocity) as a comparable HE wave, was used to calculate a transmission factor, as shown in Table 4. Values that appeared to be least subject to significant error were averaged (logarithmically) to give a mean transmission factor of $f = 0.199$.

For the purpose of transmissivity comparisons, Sedan depth of burst at 635 feet is equivalent to a scaled depth of burst of $635/W^{1/3} = 137$ feet for 1 kiloton nuclear, or 1.37 feet for 1 pound HE, assuming nuclear explosives are 50% of HE in blast production efficiency. Transmission data points for Sedan ozonosphere signals, in addition to those for the Plowshare events, Stagecoach, Buckboard, and Scooter HE tests, and for the Dannyboy nuclear event, are shown for their scaled burst depths in Fig. 7. There is a large amount of scatter in each collection. Agreement in the averages shows that the 0.199 figure from Sedan seems reasonable; deviations by a factor of 1.5 or 2.0 are not uncommon in individual measurements.

Transmissivity at long range is approximately the same as was observed by the on-site pressure gages reported by Vortman.[12] The off-site average value is not significantly larger than the on-site values, as observed on Plowshare HE cratering tests. Many individual Sedan transmissivity values are quite high; however, they may represent emissions from the higher elevation angles from the source. There were not adequate facilities or manpower available to make blast pressure measurements above Sedan; therefore no check on the nonuniform source

Table 4. Sedan Transmission Factors

Station	f	Remarks
CP-1	0.594	HE blocked by hill, f probably too large.
Argus	0.146^*	Good records.
China Lake	>0.269	Sedan slightly off-scale.
	0.351^*	Good wave records.
Valley Acres	0.304^*	Good records, early signal.
	0.185	Possible later ozonosphere HE record is obscured in early Sedan signal.
Lone Pine	>0.152	Sedan off-scale.
Deep Springs	0.091^*	Good records.
Bishop	0.217^*	Amplitude scale doubtful, may not affect relative amplitude or f values.
Tom's Place	0.201^*	Good records.
	>0.197	Sedan signal may be limited by set range.
Coaldale	0.0506 (0.0675) 0.0456 (0.0532)	Electrical noise may have added to HE value, estimated f with noise subtracted in parentheses.

*Subjectively judged to be most representative values.
Logarithmic average of starred * values = 0.199.

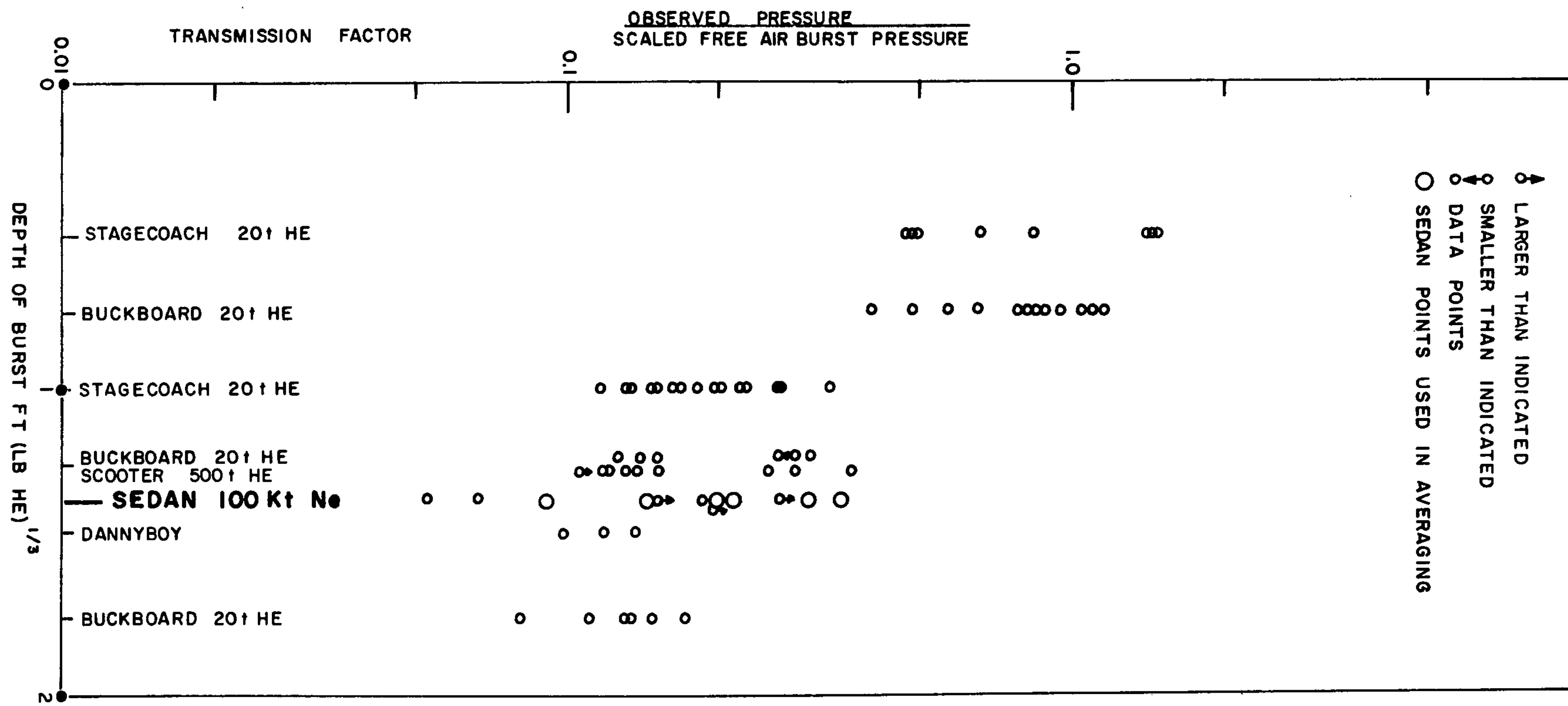

Fig. 7 Air-blast transmission factors from high-explosive and nuclear cratering tests.

wave model was possible. It would be of value if this effect, as described in the Stagecoach analysis,[1] could be verified by a measurement project on future cratering tests.

Final sound-ray calculations were made on a CDC-1604 computer at Sandia Laboratory. Ray paths, travel time, and a multiplicative factor for standard blast pressure are computed for each 1-degree increment of initial ray elevation angle. Calculated pressure-distance curves are shown in Fig. 8. Amplitudes have been normalized for 1.2 tons HE at a 15-foot height of burst, peak-to-peak pressures, and for a 1000-mb ambient sea level pressure condition. Actual microbarograph data points for the HE calibration shot are shown for comparison. Sedan data were scaled to the calibration shot yield and reduced by the 0.199 average transmission factor. Verification again frequently errs by a factor of 2. At Argus and Valley Acres in Fig. 8, a and b, significant finite pressures were recorded in calculated silence zones, although rays were calculated to land within a few miles of each station. On the average, these ray calculations slightly over-predict pressures, but this error seems small in comparison to the range of random errors encountered.

Atmospheric viscous attenuation, in theory, should reduce the overpressure of ozonosphere signals from the HE calibration shots about 40 percent. Past experiments gave some indication that this effect was observed, but it now appears from these data that the $R^{-1.2}$ decay takes this factor into account. This attenuation mainly absorbs high-frequency waves and would not significantly affect the Sedan lower frequency waves. If the attenuation were assumed, the HE data points for Deep Springs, Tom's Place, and Coaldale would be even farther above the calculated curve or the Sedan data. For the present, viscous attenuation is being ignored.

Calculated patterns are rather strongly dependent upon the temperature-height structure assumed for the ozonosphere. (Rocket measurements were made only of wind.) There was a small change in the recommended upper atmosphere temperature model between 1959 and 1962. All patterns were calculated and both temperature structures were used in the hope of finding one more useful than the other. The resulting pressure-distance patterns are quite different in appearance, as shown in Fig. 9, but in reality the differences are small and mostly

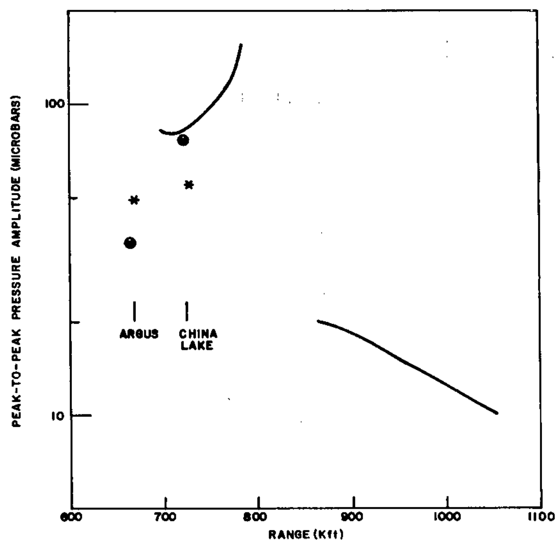

Fig. 8A

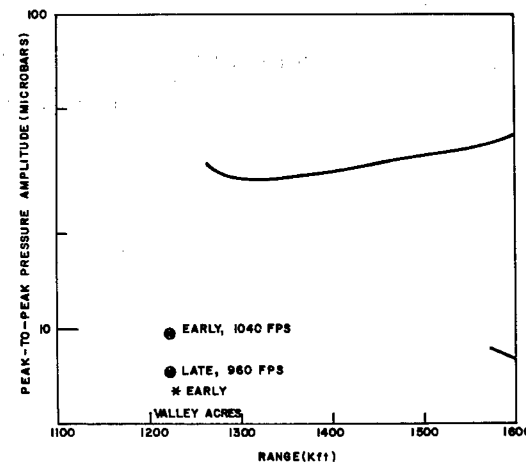

Fig. 8B

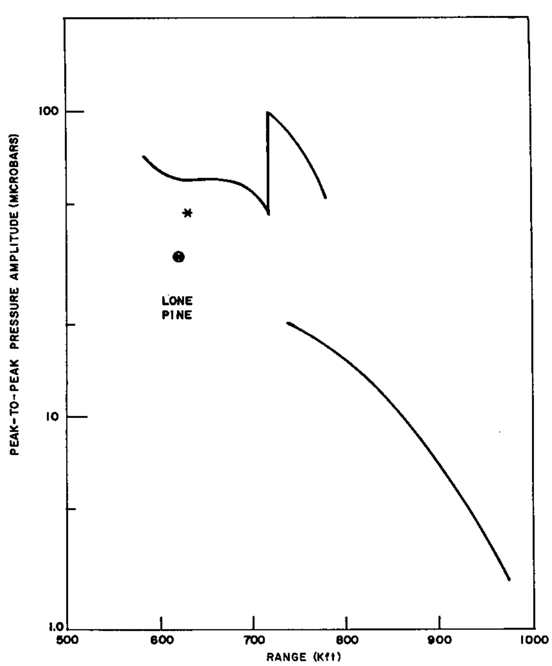

Fig. 8C

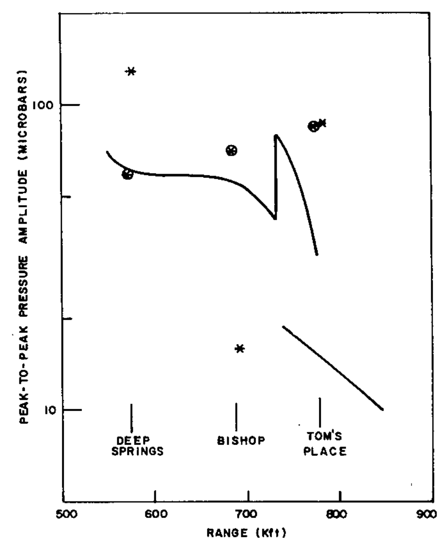

Fig. 8D

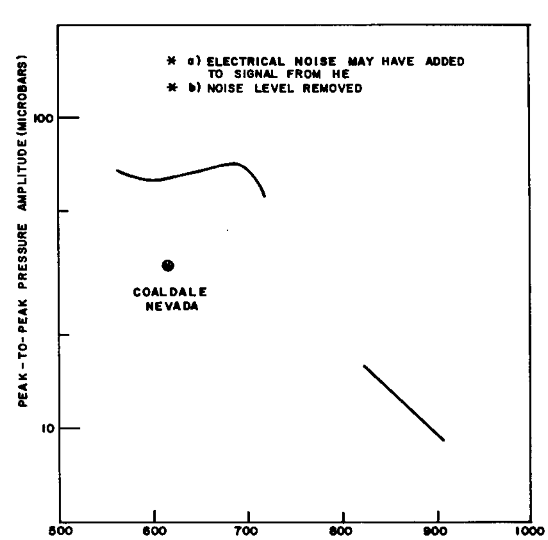

Fig. 8E

Pressure-amplitude-versus-distance predictions and observations at various direction bearings, normalized to calibration shot yield.

● Sedan
* Calibration Shot

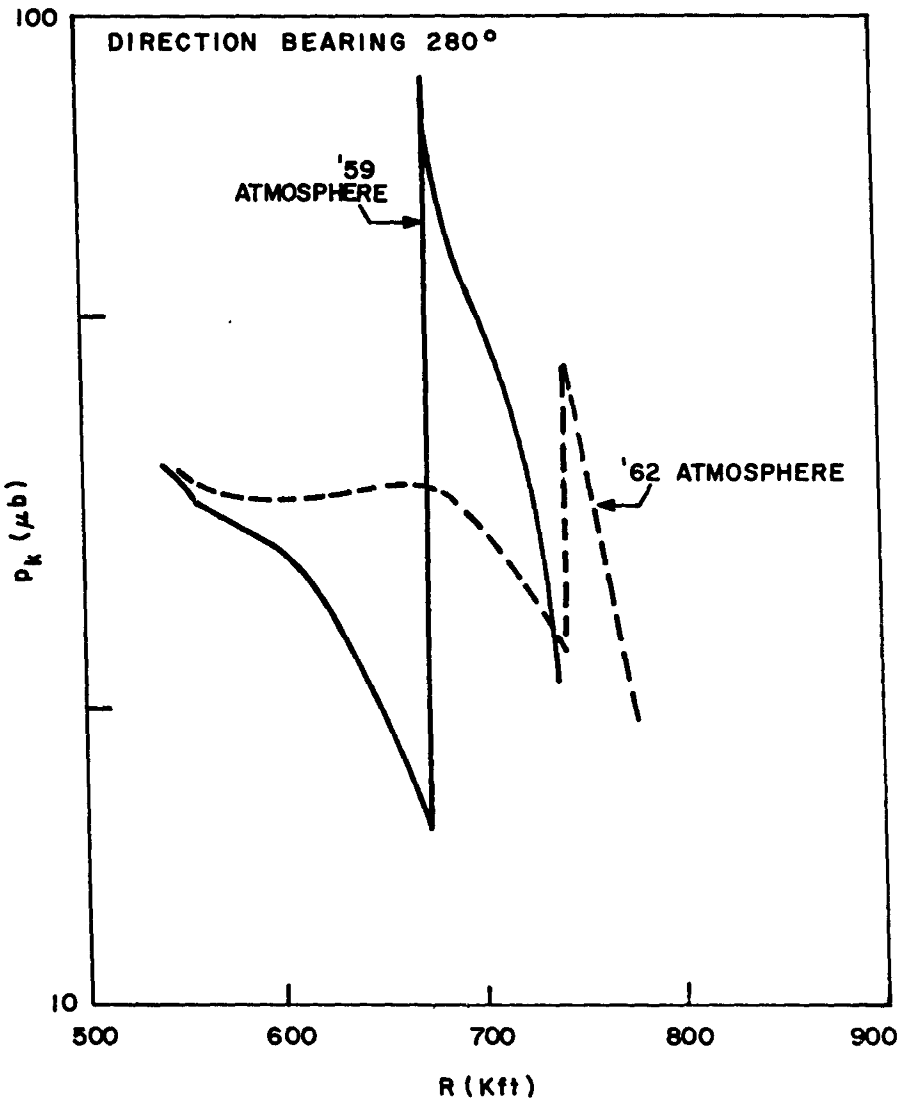

Fig. 9 Calculated pressure-distance curves from two assumed atmospheric models.

reflect changes in ray strike ranges. Also, computed versus observed arrival times do not indicate an advantage in using either model as shown in Fig. 10. Focal points and intensities are strongly dependent on detailed temperature and wind structures, and thus show up as large pattern changes. With the accuracy of wind observations currently attainable at these levels, however, the assumed temperature model change is really of little significance; the same holds for the ragged features of the pressure-distance prediction. Final calculations in Fig. 8, therefore, were made from the most recent 1962 ARDC Model Atmosphere temperatures.

In Fig. 8d it is of interest that the Sedan data gave a smoother pressure-distance curve than did either the HE data or the ray calculation. For long wavelength signals, it may be true that detailed effects of atmospheric layering are smoothed. If so, large yield predictions may be made with smaller errors than are indicated by the bulk of HE data collected to date. Only large quantities of statistical data could firmly verify this conclusion, but large quantities would also be required to determine adequately the distribution of errors when data scatter is as large as has been observed here. It may be of value on future nuclear cratering tests to increase the number of microbarograph observations to determine whether results from large yields are more uniform than are those from smaller yields. If so, off-site safety problems posed by large probable errors and by computed foci may be appreciably reduced.

Verification is graphically shown in Fig. 11, with predicted plotted against observed pressure amplitudes for the HE calibration shot. Calculated values are the ranges of pressures predicted to land within 5, 10, and 20 miles of the station. In every case, a silence zone was predicted to exist within 20 miles of the station. Only the Deep Springs pressure exceeded all prediction; other observed values were predicted to land within 20 miles of the recording station.

Scaling to Large Excavation Yields

Microbarograph measurements on both HE and Sedan shots have been extrapolated to a 50-megaton-yield device at 1.37 ft/(lb)$^{1/3}$, or 5040 feet depth of burst, in Fig. 12. Resulting upper-bound pressure curves for 50 and 10 megatons are shown. If 4-mb amplitudes are the limit for off-site safety, based on NTS experience with Las Vegas and St. George, damage could extend 385 miles downwind (ozonosphere) from the 50-megaton shot or 230 miles from the 10-megaton shot.

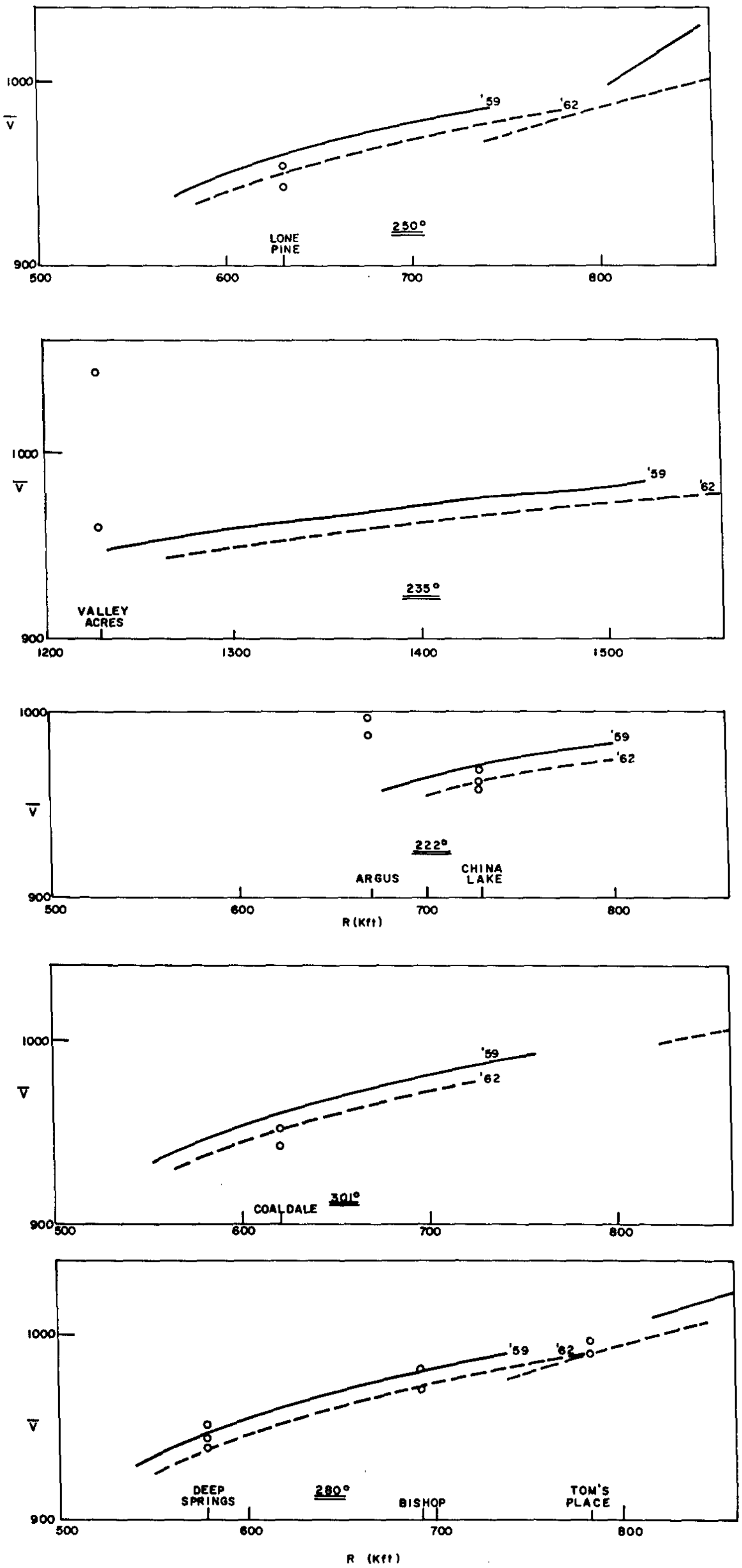

Fig. 10 Calculated mean speeds to wave arrival for two assumed atmospheric models.

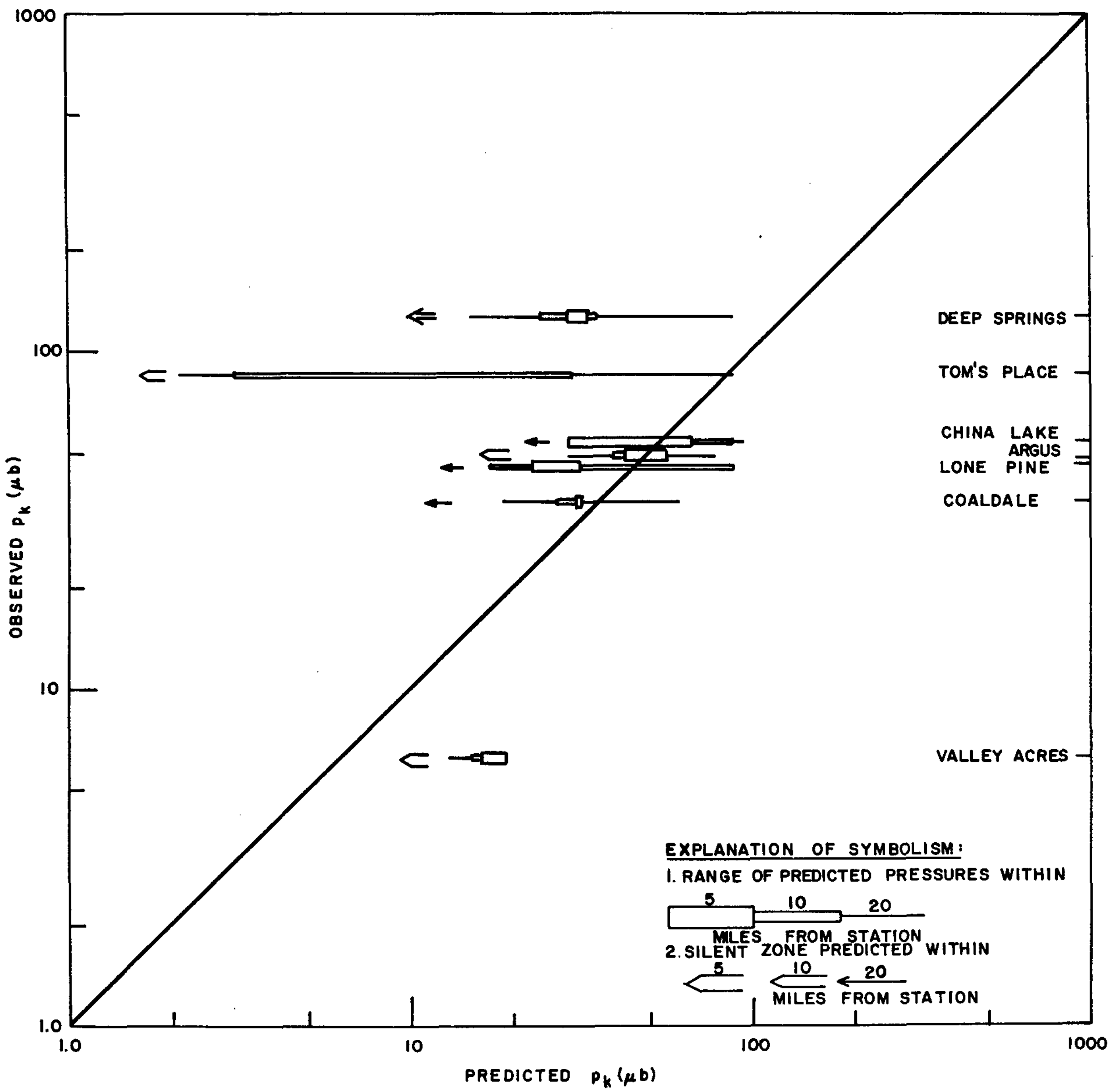

Fig. 11 Verification scatter diagram for HE calibration shot.

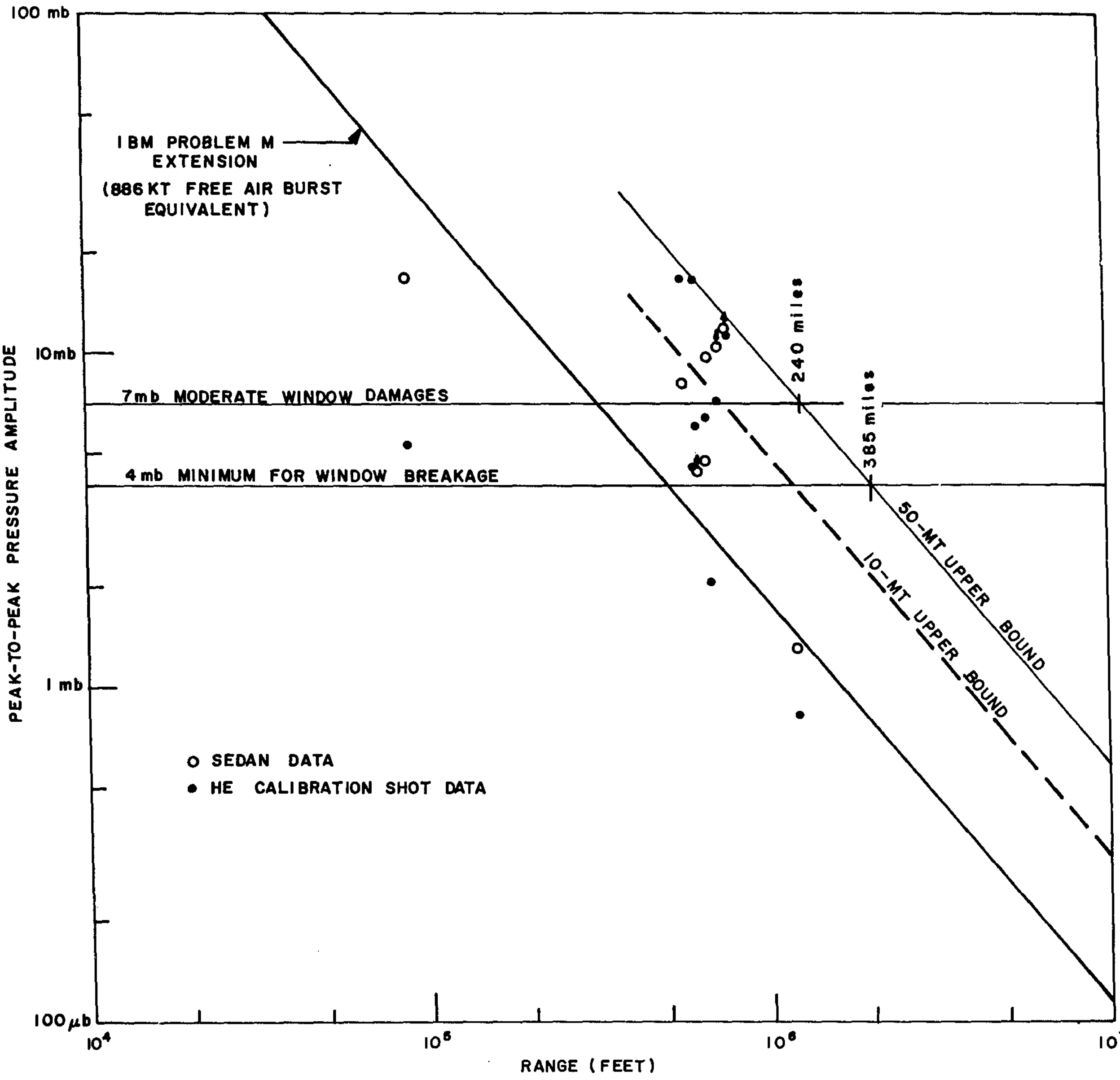

Fig. 12 Pressure-distance data extrapolated to 50-mt cratering shot.

If a 7-mb limit were acceptable, allowing for minor damage to smaller towns or villages which could possibly be provided for by warning and repair arrangements, then downwind concern would only extend 240 miles from 50-megaton, or 140 miles from 10-megaton, shots. At crosswind or upwind bearings from these yields, the range of possible damage from ozonosphere propagations would be considerably reduced.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Air blast pressures from Sedan at large distances (100 to 240 miles) averaged about 20 percent as large as would have been recorded from the same yield from a free-air burst detonated at the same time. Specific signal comparisons showed that this transmission factor varied from 5 to 35 percent.

2. Rocket wind data and the 1962 ARDC Standard Atmosphere temperatures allowed ray calculated pressure predictions for ozonosphere propagations to be made which generally were verified within a factor of 2. Most observed pressure values were predicted to land within 20 miles of the recording stations.

3. Observed pressure patterns from large shots may be more uniform than either calculations or scaling from HE calibration shots would indicate. This may be a result of long wavelengths smoothing out atmospheric detail effects.

4. Results, scaled to 50 megatons at similar $W^{1/3}$ scaled burst depth, indicate that minimum window-breaking pressures (4 mb) may propagate to 385 miles downwind.

Recommendations

1. Future large cratering tests should be documented with similar microbarograph measurements to gain further statistical information and to ascertain repeatability of the average transmission factor.

2. A greater number of recordings should be made on each shot to establish whether large yield blast patterns are really more uniform than refraction calculations and HE data would indicate.

3. Comparison tests of height-of-burst effects at long range from surface-burst and 15-foot tower-burst 1.2-ton HE shots should be performed in order that adequate re-evaluation of Stagecoach data may be carried out.

4. Additional measurements should be made in the second sound ring (200 to 300 miles) to verify the longer range propagation predictions for damaging waves from 50-megaton cratering blasts.

5. Rocket temperature measurements should be devised to ascertain whether differences between various standard atmosphere ozonosphere temperatures are real or pertinent to NTS conditions.

6. Close-in blast measurements above cratering bursts should be made to establish the source of the relatively large amplitude propagations recorded at long range.

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STL	Space Technology Laboratories, Inc., Redondo Beach, Calif.
SC	Sandia Corporation, Sandia Base, Albuquerque, New Mexico
USC&GS	U. S. Coast and Geodetic Survey, San Francisco, California
LRL	Lawrence Radiation Laboratory, Livermore, California
LRL-N	Lawrence Radiation Laboratory, Mercury, Nevada
Boeing	The Boeing Company, Aero-Space Division, Seattle 24, Washington
USGS	Geological Survey, Denver, Colorado, Menlo Park, Calif., and Vicksburg, Mississippi
WES	USA Corps of Engineers, Waterways Experiment Station, Jackson, Mississippi
EGG	Edgerton, Germeshausen, and Grier, Inc., Las Vegas, Nevada, Santa Barbara, Calif., and Boston, Massachusetts
BYU	Brigham Young University, Provo, Utah
UCLA	UCLA School of Medicine, Dept. of Biophysics and Nuclear Medicine, Los Angeles, Calif.
NRDL	Naval Radiological Defense Laboratory, Hunters Point, Calif.
USPHS	U. S. Public Health Service, Las Vegas, Nevada
USWB	U. S. Weather Bureau, Las Vegas, Nevada
USBM	U. S. Bureau of Mines, Washington, D. C.
FAA	Federal Aviation Agency, Salt Lake City, Utah
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